The Open University

**Science Supplementary Material**
**SM358 The Quantum World**

# SM358

# Introduction and Guide

**Welcome to SM358 *The Quantum World*. We hope you will find this module interesting, thought-provoking and fascinating.**

## READ THIS FIRST

**This Guide should be the first SM358 document you read. In it we outline the aims of the module, and provide details of the learning materials, the website, tuition and assessment arrangements, and whom to contact if you have queries.**

## Contents





6.1 PT/TeX

# 1 General aims of SM358

Quantum mechanics has changed the way we understand the world. It shakes our intuitions and replaces classical mechanics with a set of principles that allows us to understand Nature on the scale of atoms and below. This module will teach you the principles of quantum mechanics and the mathematical techniques needed to state and apply them. You will explore the interpretation of quantum mechanics and see the extent to which quantum mechanics has been tested by experiment. You will also see how quantum-mechanical methods are used to understand the properties of atoms, molecules and solids.

The aim of Book 1 is to introduce the basic principles of quantum mechanics using an approach pioneered by Schrödinger, called *wave mechanics*. Book 2 looks at deeper aspects of the subject, involving identical particles, spin and a remarkable phenomenon called *entanglement*. Finally, Book 3 shows how quantum-mechanical methods are used to understand the behaviour of matter, including atoms, molecules and solids.

The discoverers of quantum mechanics were shocked by their creation. Common-sense ideas had to be abandoned – for example, the belief that a particle follows a definite trajectory through space. No doubt you will find many things in SM358 that amaze you, and we hope that you will find this as delightful as it is challenging. But quantum mechanics does not set out to be provocative; like any branch of physics, it aims to explain the world around us, and it has had unparalleled success in doing this. You will see that quantum mechanics explains why the Sun has shone so brightly for so long, why atoms have their characteristic properties and why some solids conduct electricity easily. Quantum mechanics is used to design microscopes, lasers and semiconducting materials, and to share encryption keys without any risk of undetected eavesdropping. It is not only amazing; it provides the concepts and quantitative predictions needed by applied physicists, chemists and technologists who wish to interpret and control phenomena on the nanoscale and below.

# 2 Assumed prior knowledge

When preparing SM358, we made some assumptions about your knowledge and understanding of physics and mathematics. If you have good passes (at Grade 3 or above) in both S207 *The Physical World* and MST209 *Mathematical methods and models*, you should be well prepared.

The mathematical prerequisite is especially important, as it would be difficult to study SM358 successfully without the necessary mathematical background. In particular you should be familiar with complex numbers, vectors, matrices, differential equations and partial differentiation. We also assume that you have some knowledge of physics, especially mechanics (including Newton's laws, energy, momentum and angular momentum) and waves (travelling and standing waves and the phenomenon of interference). S207 is the ideal physics module for these topics; it also contains an introduction to quantum mechanics which should be helpful, although SM358 does not assume any prior knowledge of quantum physics.

If you are not confident that you are suitably prepared, we strongly advise that you work through the questions in the *Are you ready for SM358?* booklet, which can be downloaded from the SM358 website (accessible from your StudentHome page) or from the Science Faculty website http://www.open.ac.uk/science/ (click on *Stuying Science* and then *Are You Ready for Science*). The booklet has suggestions for materials that you can study to fill in any gaps in your knowledge or skills. Prior to allocation to a tutor, you should contact a member of the Physical Science Student Support Team (see page 5) if you are unsure about your preparedness for SM358. You should also discuss any concerns with your tutor as soon as you can.

# 3 Learning materials

The learning materials for SM358 include three books with two accompanying DVDs, plus a *Glossary* of terms used in the module.

## 3.1 Books

The main printed material is presented in three books, which will be sent to you at the start of the module.

**Book 1**, *Wave mechanics*, begins with a wide-ranging introduction to the quantum revolution, emphasizing the fact that the fundamental laws of physics are inherently probabilistic. It then introduces Schrödinger's equation, together with the concepts of wave functions and stationary states. We show how probability distributions are characterized by expectation values and uncertainties, and explain the significance of the uncertainty principle. Schrödinger's equation is solved for simple model systems, such as particles in boxes and harmonic oscillators, and used to model quantum dots and vibrating diatomic molecules. The concept of a wave packet is introduced and used to describe the motion of particles and to explore the classical limit of quantum mechanics. Finally, the quantum processes of scattering and tunnelling are discussed, together with their application to scattering experiments, radioactive alpha decay, stellar astrophysics and the scanning tunnelling microscope. The mathematical techniques used and developed in this book include complex numbers, the separation of variables, differential equations and eigenvalues.

**Book 2**, *Quantum mechanics and its interpretation*, begins by giving a more general discussion of quantum-mechanical principles. It shows how quantum states can be represented by vectors in an abstract vector space. The vector-space formalism is used to provide a proof of the uncertainty principle and to derive quantum-mechanical conservation laws. We then see how angular momentum is described in quantum mechanics. It turns out that particles such as electrons and protons have a new form of angular momentum, called *spin*; MRI body scanners manipulate and monitor the behaviour of spins of protons in living tissue to obtain valuable medical images. The book also explains how to describe many-particle systems. You will see that collections of identical particles can exhibit remarkable behaviour based on the Pauli exclusion principle and Bose–Einstein condensation. The book closes by discussing the fascinating topic of entanglement, including predictions that were once held to be implausible, but have been supported by the results of recent experiments. The applications of entanglement include quantum key distribution and quantum teleportation. The mathematical techniques used and developed in this book include abstract vector spaces, Hermitian operators and matrix algebra.

**Book 3**, *Quantum mechanics of matter*, shows how quantum-mechanical methods are used to explain the behaviour of matter, from the scale of atoms to molecules and solids. The hydrogen atom is discussed in detail, as well as hydrogen-like systems such as positronium. Useful techniques such as perturbation theory and the variational method are developed to obtain approximate results in cases where exact calculations become difficult. The book then goes on to discuss many-electron atoms and the Periodic Table, molecular binding and the behaviour of electrons in the energy bands of metals, insulators and semiconductors. Finally, the book considers the interaction of matter with light. You will see how quantum mechanics can predict selection rules, the lifetimes of atomic states and the brightness of spectral lines.

**E-text** The three books will also be accessible in e-text format on the SM358 website. The e-text will be searchable, so you can find the references to any term of interest, e.g. *uncertainty principle*. We do not expect you to print out large sections of the book, though there may be occasions when printing a chapter to take to study on a beach, for example, is a better option than taking one of the books.

**Worked examples and exercises** The books contain many worked examples and exercises, and these should play an important part in your learning. The worked examples illustrate important skills, and should be studied where you meet them in the text. Tackling the exercises is also a vital part of the learning process, since this allows you to gauge your understanding of the text and prepare for assignments. We strongly recommend that you attempt each exercise as soon as you meet it in the text.

**Reference material inside covers** The inside front cover of each book contains a list of important and useful physics equations. Some of these equations and relationships may not be particularly meaningful at the start of the book, but by the time you complete it you should be familiar with all of them. Inside the back cover you will find further useful relationships, such as a list of integrals, and a table of physical constants. You should find this reference material invaluable when tackling the exercises and assignment questions.

## 3.2 DVDs

The two SM358 DVDs contain interactive computer packages and video material.

The computer packages give you the chance to explore the predictions of quantum mechanics in a variety of contexts, including particles in one-dimensional wells, wave packets, scattering, tunnelling, angular momentum and the hydrogen atom. These simulations should help you to develop some intuition for the way quantum mechanics works; this is especially valuable because ordinary intuition, based on classical physics, can be deceptive.

Three of the video sequences show a tutor going through the solution of typical TMA questions with a student. The first of these should be watched before tackling TMA 01; the other two can be viewed before TMA 02. The remaining video sequences consist of two films relating to modern applications of quantum mechanics (scanning tunnelling microscopes and quantum information) and two older Open University videos (*The Stern–Gerlach experiment* and *Ghostly action at a distance*). The SM358 *Study Planner* indicates the recommended times to study these software and video resources.

A number of other software applications which may be of use during your studies (such as Adobe Reader and OpenOffice) are available to download from the online *Computing Guide*, which you can access from StudentHome.

## 3.3 Glossary

The SM358 *Glossary* contains descriptions of concepts and terms used in the module, and indicates relationships between them. This glossary is intended to be a handy source of reference while studying the books, and should also be useful for revision.

Apart from the full SM358 *Glossary*, we have prepared a cut-down version for Book 1 only. You may prefer to use this while studying Book 1 as it avoids references to terms whose meaning will only become clear later in the module. Similarly, there is a glossary for Books 1 and 2 only, which you can use while studying Book 2. All these glossaries are available on the SM358 website.

## 3.4 Mathematical and Physics toolkits

In each of the first two books of SM358 the last chapter is a *Mathematical toolkit* which reviews key mathematical topics needed to understand the material covered by that book. It is designed to give you some flexibility in studying the material depending on your background and prior knowledge of mathematics. If you are confident in your mathematical preparation you need only dip into the mathematical toolkits as and when you need to. Look out for the green study comments in the main texts that refer you to the appropriate part of the toolkit. If, however, you feel less prepared, you may wish to invest more time revising and reviewing this material.

Similarly, if your background is mainly in mathematics and you feel less confident about the prerequisite physics, you may wish to refer to the *Physics toolkit*. This document is a glossary of prerequisite physics terms and is available from the SM358 website only. It is best studied at the beginning of the module although you may wish to refer to it again as you progress though Books 1 and 2.

# 4 Website

The SM358 website (accessible from your StudentHome page) is an important source of information and resources which will be added to during the year. You should aim to check the website every few days for new postings. The website will contain the following:

- The *Study Planner*, which provides a schedule for studying SM358;
- Latest news about SM358;
- Any important errata for the SM358 materials and assignments;
- Information about e-tutorial scheduling and topics;
- The e-text versions of the books;
- The assignment booklets;

- Access to the eTMA and iCMA systems;
- The *Glossary*;
- The *Physics toolkit*;
- Additional exercises and solutions for each book;
- Access to the SM358 forums;
- Revision materials and *Specimen Examination Paper* ;
- Additional resources to help your understanding, including screencasts and answers to frequently-asked questions.

# 5 Tuition

Tuition on SM358 is organized through the Physical Science Student Support Team which operates across Level 3 physics and astronomy modules. The team will include module tutors, pathway tutors and curriculum staff. See the table on pp. 11 and 12 for details of how to contact the Team.

You will be allocated a module tutor who will mark your TMAs and will be able to provide help with SM358 during the year. We advise you to talk to your tutor very early in the year. He or she may be able to put you in contact with other SM358 students, with whom you could form a self-help group. *You should not hesitate to contact your tutor about any academic question that you have relating to SM358.* You will also be assigned a pathway tutor who has responsibility for guiding your progress through and beyond SM358, as you study further with the OU. In addition you may be contacted by, or may need to contact, other members of the Physical Science Student Support Team who have responsibility for particular aspects of SM358's presentation.

All of the tuition will be provided electronically. The e-tutorials will be run using a real-time collaboration system, which allows synchronous communication of images, whiteboard writing, text and sound between tutors and groups of students. A typical module-wide tutorial might include a short lecture and present the step-by-step solution of a problem, followed by an opportunity for questions and discussion. Details of the timing of these tutorials, which will be open to all SM358 students, will be posted on the website. With the permission of participants, these sessions may be recorded so that they can be viewed at a later date. Your tutor will also arrange sessions to provide direct help with specific topics. These sessions may also be recorded with the permission of the participants.

The real-time collaboration system will also be used to provide additional support, in which direct help is given to students who have had difficulty with individual iCMA questions. In order to benefit from this, it is essential for you to do the iCMAs on time, working to the cut-off dates/recommended completion dates in the *Study Planner*.

To participate in e-tutorial sessions, you will need an internet connection and a computer with speakers. A microphone is also required if you wish to communicate with the tutor and other participants via speech. Whilst it is possible to interact without a microphone (by using typed text) you will probably get more from the tutorials by using a combined headphone–microphone headset which helps to avoid audio feedback problems. This is particularly advisable if you want to take advantage of individual or small-group help sessions on particular topics.

There will be SM358 forums which you can use to ask questions or discuss aspects of the module with other students. One advantage of sending questions to the forums is that members of the Physical Science Student Support Team will drop in, read the messages and provide answers where appropriate.

# 6 Assessment

The continuous assessment consists of six core interactive computer-marked assignments (iCMAs 51–56) and four tutor-marked assignments (TMAs 01–04). At the end of the module, there will be a three-hour written exam. Your final grade will be determined solely by your exam mark, provided that your engagement with the continuous assessments has met certain threshold standards.

**To be eligible for a passing grade, you must engage satisfactorily with *at least seven* of the ten assignments, *at least two* of which must be TMAs. The threshold for satisfactory engagement is not high. If you score 30% or more on any assignment (iCMA or TMA), you will automatically be judged to have engaged satisfactorily with that assignment. Please note that high marks on one assignment do not compensate for low marks on another; you will need to score 30% (or more) on seven individual core assignments (or more) to satisfy the continuous assessment threshold.**

However, you should certainly *not* treat the minimum threshold for continuous assessment as your target. The assignments are carefully designed to be a central part of your learning. You are strongly advised to complete as many of them as possible, and to aim for marks that are much higher than the minimum threshold of 30%. This is very important if you are to be adequately prepared for the final exam. We know from many years of experience that there is a close correlation between performance in continuous assessment and in the exam. By getting high marks on the continuous assessment, you will be doing the work needed to get a high exam mark, and you will be getting invaluable feedback which will help you improve your performance.

For more evidence on the strong link between the continuous assessments and exam results, please look at the document *Why continuous assessment matters in SM358*, which is available on the SM358 website. This should convince you that you will greatly increase your chances of getting a high exam grade by doing as many core assignments as you can (and preferably all 10).

**In summary, to obtain a credit in SM358, you must have demonstrated satisfactory engagement with the continuous assessment (as specified above) and you must pass the final exam. The grade you obtain will then be determined solely by your exam mark. It is advantageous to do as many assignments as possible.**

## 6.1 The iCMAs

The iCMAs are all accessible from the SM358 website.

**The iCMAs will NOT be sent to you in the post.**

The iCMAs cover some of the most important topics and skills in SM358. They have the great advantage of giving you instant feedback and hints, so if you get an answer wrong at your first or second attempt, you will be guided towards getting it right. Even if you get an answer wrong on your final attempt, you will be able to try a similar question on the same topic, and continue in this way until you are successful. If you still have difficulties, your tutor may be able to organize an individual or small-group e-tutorial session to give help on a specific topic.

Because of their built-in hints and the possibility of multiple attempts, you should aim to get high scores in the iCMAs – preferably above 70%. If you do not achieve this to begin with, you should have another go at the assignment, trying for a higher mark. This iterative approach should guarantee that you have understood most of the key concepts and techniques of quantum mechanics, and will mean that you are in a very good position to perform well in the exam. In fact, some of the questions in the iCMAs will be very similar in type to those in the first half of the exam, so there is even more motivation for getting them right!

The six core iCMAs (iCMA51–iCMA56) all count towards the continuous assessment threshold. These assignments are regularly paced throughout the module, with two for each of the three books. The first two core iCMAs (51 and 52) have cut-off dates close to the corresponding period of study. If you miss these dates, these iCMAs will not count towards your continuous assessment threshold. We therefore advise you to tackle individual questions in these iCMAs whilst you are studying each chapter, completing the test over a number of weeks. Alternatively, you can tackle the whole assignment in one go. Whichever method you use, be sure to click on 'End test' and the 'Finish' button before the cut-off date (whether you have answered all the questions or not). After the cut-off date, you can open fresh versions of these iCMAs (iCMA51–Practice and iCMA52–Practice) and use them for practice purposes, but your mark will no longer count.

The remaining core iCMAs (53–56) have recommended completion dates listed in the *Study Planner*. We advise you to stick to these dates to help pace your study through the module, to help you prepare for TMAs and to allow

your tutor to give you support when it is most needed. iCMAs 53–56 have the same formal cut-off date close to the end of the module (see the *Study Planner* for more details). On this date, your best score on each iCMA will be recorded and will be made available to the Examination and Assessment Board, so you must be sure to click on 'End test' and the 'Finish' button before the formal cut-off date if these iCMAs are to count towards your continuous assessment threshold. In previous years, a few students have delayed tackling the iCMAs, perhaps with the intention of trying them closer to the exam. This is a very bad plan. There will be additional Revision Medley iCMAs to help prepare for the exam, but iCMAs 51–56 are designed to be an integral part of your studies, to be used regularly as you read the main texts. These iCMAs will help you gain the skills you need to tackle TMA questions, and completing them on time will ease your study of later chapters.

In addition to the core iCMAs, there are extra iCMAs which do not count towards the continuous assessment threshold. At the start of SM358, iCMA Maths is an assignment that we expect all students to complete because it focuses on the key mathematical skills needed in Book 1. It is extremely important to attempt this iCMA as soon as possible, so that you can identify any areas you need to review. If you have specific difficulties, and can identify them early enough, the Physical Science Student Support Team will try to provide targeted help, and this could be invaluable. Also, at the end of the module, we will release medleys of iCMA questions based on the core iCMAs. These are designed to help you to revise before the exam.

## 6.2 TMAs

There are four tutor-marked assignments (TMAs), which will be available to download from the SM358 website at appropriate times during the module.

**The TMAs will NOT be sent to you in the post.**

Each TMA covers a different part of SM358, as follows.

TMA 01 relates to Book 1, Chapters 1–4.

TMA 02 relates to Book 1, Chapters 5–7 and Book 2, Chapter 1.

TMA 03 relates to Book 2, Chapters 2–7.

TMA 04 relates to Book 3, Chapters 1–6.

You should note that even though Chapters 7 and 8 of Book 3 are not assessed by a TMA, they are assessed by iCMA and **they may be assessed in the exam**.

The TMA questions focus on key parts of SM358 and cover many of the skills you will need in the second half of the exam. They are designed to assess whether you have achieved the learning outcomes for the module, which are summarized in Section 6.5 below. Tackling the assignment questions is an important part of the learning process, since they will often require you to synthesize information from a number of areas, and to apply your knowledge and understanding in new ways. The TMAs will also help you to identify your strengths and the parts of the module that you need to spend more time on or that you need help with. The comments and feedback that you receive from your tutor will also contribute to your learning, and we strongly recommend that you look carefully at the advice that you receive. Screencasts giving further guidance on answering the TMA questions will be available on the website a few weeks after the TMA cut-off dates.

Each TMA has a fixed cut-off date close to the relevant study period. Any extensions require prior permission from your tutor, and it will never be possible to have an extension of more than three weeks. In the context of this module, where your final grade is determined by your exam score, it is fine to ask your tutor for hints or advice if you get stuck on any particular question. At least two TMAs must be submitted to satisfy the continuous assessment threshold.

You are normally expected to submit all your TMAs electronically, using the on-line eTMA system. You can submit a word-processed document, or a scanned version of a hand-written one; advice on how to produce an eTMA will be provided on the SM358 website. The eTMA system allows for TMA submission directly to the University 24 hours a day, and either gives you confirmation that your eTMA has been submitted successfully or, if there has been a problem, an error message informing you of the problem and what steps you should take to overcome it.

To submit your TMAs electronically you will need to:

1. Log on to StudentHome.
2. Click on the 'assessment' link under the relevant module on your StudentHome page.
3. Click on the 'submit' link alongside the TMA you want to submit and follow the onscreen instructions.

General information about policy and procedure can be found in the *Assessment Handbook* which you can access from your StudentHome page.

Under certain circumstances, you can ask your tutor whether paper submission of your TMA will be acceptable. These circumstances could be, for example, your experience that typesetting equations electronically, or incorporating scanned images in your electronic document, would take you an unacceptably long time; or it might be that your computer is temporarily out of use. **Please note that, before submitting a TMA on paper, you must contact your tutor and obtain his/her agreement.**

If your tutor agrees to you submitting by post, you should be sure to post your TMA in sufficient time to arrive by the cut-off date. Do not send it using recorded delivery or guaranteed delivery; this can cause problems for tutors who are not at home to receive it. Instead, send it by first class post and ask for a proof-of-posting certificate at the post office and be sure to keep a copy of the assignment. If, for any reason, you are unable to complete your TMA on time, you must contact your tutor before the cut-off date to discuss possible options. Under exceptional circumstances your tutor may allow an extension, but this will be of limited duration (no more than three weeks). The procedure for late submission of assignments is given in your Assessment Handbook.

## 6.3 Examination

The three-hour written examination will be held in October. A *Specimen Examination Paper* (*SEP*), with *Solutions*, will be made available on the SM358 website. Details of the examination date and your examination centre will also be sent to you during the year. Use of a **scientific calculator** is allowed in the examination, but the calculator must not be programmable and must not be able to store text.

**Memorizing equations?** You will discover that there are some equations in quantum mechanics that are used frequently. However, although it is often helpful to be able to recall these equations, we do not intend the examination to be a memory test. The *SEP* is accompanied by an *Equations booklet* that you might need to use in the examination, and the same booklet will be attached to the final examination paper. The equations will not be named or explained, but are simply listed to jog your memory. This means that you need to understand the meaning of these equations, and be able to recognize them and know when and how to use them, but you do not need to commit them to memory. We recommend that you use the equation list when you tackle revision questions, such as those on the *SEP*, so that you will immediately know where to find what you need in the final exam.

## 6.4 Plagiarism

Plagiarism is using the work of other people to gain some form of benefit without formally acknowledging that the work came from someone else. For further information and advice on what constitutes good academic practice (and hence how to avoid plagiarism) please go to the *Developing good academic practice* website at http://learn.open.ac.uk/site/dgap001/. To check that all students are working in a fair and appropriate manner, the Open University is currently using text-comparison software to detect potential cases of plagiarism in work that is submitted for assessment. Details of how this is implemented in this module are given on the SM358 website.

## 6.5 Learning outcomes

SM358 provides opportunities for you to develop and demonstrate knowledge and understanding, qualities, skills and other attributes in the following four areas.

**Knowledge and understanding of**

1. the fundamental principles and methods of quantum mechanics;
2. terms and notation appropriate to quantum mechanics;
3. language and techniques of mathematics used in quantum mechanics;

4. standard interpretations of quantum mechanics, including issues related to entanglement;
5. ways in which quantum mechanics is applied to real physical systems.

**Cognitive skills** You will be able to

1. use and apply the concepts and formalism of quantum mechanics;
2. interpret phenomena from a quantum-mechanical perspective;
3. use appropriate mathematical language and techniques to understand quantum-mechanical phenomena and to solve problems in quantum mechanics;
4. make appropriate approximations when using quantum mechanics to model real systems;
5. critically evaluate the extent to which aspects of quantum mechanics have been tested by experiment.

**Professional skill** You will be able to

1. manage your own learning and time, and be able to learn independently so that you can continue your personal and professional development after completing the module.

**Key skills** You will be able to

1. locate, receive and use a variety of sources of information (textual, tabular, equations, diagrams, audio-visual and computer-based);
2. study effectively by acquiring general skills from specific worked examples and exercises;
3. communicate complex information accurately and unambiguously via written work with appropriate use of notation, units, equations and diagrams.

# 7 General advice

The *Study Planner* on the SM358 website is an important tool because it provides a schedule for studying the module. It indicates which chapter you should be studying in a particular week. It also indicates any DVD activities scheduled for the week and shows when assignments are due. We strongly recommend that you stick as closely as possible to this schedule, moving on to each new chapter as indicated to avoid cumulatively slipping behind. If you do find yourself slipping behind, you should contact your module tutor to discuss strategies for catching up.

You should regard the iCMA recommended completion deadlines and cut-off dates and the TMA cut-off dates as key deadlines. You may wish to tackle each question immediately after studying the part of the module to which it relates, rather than tackling all of the questions at once. Note that there are four 'consolidation weeks' built into the schedule, which should help you to submit the assignments on time.

**Feedback to the SM358 Team** We welcome your comments about SM358, whether positive or negative. In particular, although we have a fairly robust system of checking and quality assurance for the materials, some errors may slip through. So if you notice any mistakes in SM358 (for example, misprints that make nonsense of an important sentence or an assignment question) which you think need correcting as soon as possible, please contact the SM358 Curriculum Manager. Please don't assume someone else has done so.

# 8 Other books on quantum mechanics

The SM358 materials are designed to provide the information and develop the skills required to achieve the learning outcomes (Section 6.5). However, there may be occasions when you wish to consult other books, either for an alternative viewpoint on topics that are part of the module, or to find out about topics in quantum mechanics that are not included in the module, or even to see a more advanced treatment of some topics. The books listed below are those that we would recommend. Note that there is quite a lot of variation in the notation used in different quantum mechanics books, and this can be confusing.

**Books at about the same level as SM358**

- A. P. French and E. F. Taylor *An Introduction to Quantum Physics* (Nelson Thornes) ISBN 0 7487 4078 3
- R. Eisberg and R. Resnick *Quantum Physics of Atoms, Solids, Nuclei and Particles* (John Wiley and Sons) ISBN 0 471 87373 X

- F. Mandl *Quantum Mechanics*, (The Manchester Physics Series, John Wiley and Sons) ISBN 0 471 93155 1
- D. Bohm *Quantum Theory* (Dover, New York, 1989) ISBN 0 486 65969 0

**The interpretation of quantum mechanics**

- R. P. Feynman, R. B. Leighton and M. Sands *Feynman Lectures on Physics Volume 3* (Addison Wesley) ISBN 0 201 021153 (paperback, 1970) ISBN 0 8053 9045 6 (hardback, 2006)
- J. S. Bell *Speakable and unspeakable in quantum mechanics* (Cambridge University Press, 1987) ISBN 0 521 52338 9
- G. Greenstein and A. G. Zajonc *The quantum challenge* (Jones and Bartlett, Sudbury) ISBN 0 7637 02161

**More advanced textbooks**

- A. Messiah *Quantum Mechanics* (Dover, New York, 2000) two volumes bound as one ISBN 0 486 40924 4
- C. Cohen-Tannoudji, B. Diu and F. Laloë *Quantum Mechanics* two volumes (Wiley, New York) ISBN 0 471 16433 X and ISBN 0 471 16435 7

# 9 Whom should you contact if you have queries or problems?

The table below gives a list of useful contacts if you have difficulties or queries relating to your studies.

Your StudentHome page at **http://www.open.ac.uk/students** also provides many points of contact.

| If you have queries or problems relating to: | Whom to contact: |
|---|---|
| Academic aspects of SM358; clarification and/or help with the module materials; queries about TMAs or iCMAs. | Your tutor. Contact details are on StudentHome |
| Non-receipt of a marked TMA. | First contact your tutor, then if necessary the Physical Science Student Support Team<br>Email: physical-science-support@open.ac.uk<br>Telephone: +44 (0)845 366 0474<br><br>Otherwise, if you need to contact the central OU:<br>Telephone: +44 (0)1908 653051<br>Write to:<br>Assignment Handling Office<br>The Open University, PO Box 722<br>Milton Keynes MK7 6ZT |
| Problems contacting your tutor or anything related to tutor support. | The Physical Science Student Support Team<br>Email: physical-science-support@open.ac.uk<br>Telephone: +44 (0)845 366 0474 |
| Information about online tutorial dates and times. | The SM358 website or the Physical Science Student Support Team<br>Email: physical-science-support@open.ac.uk<br>Telephone: +44 (0)845 366 0474 |
| Non-receipt of, incomplete, or damaged materials, including CD-ROMS/DVDs; requests for replacement materials if you lose or damage items. | In StudentHome click on 'materials despatch'<br>Telephone: +44 (0)1908 332633 |
| Queries about computer hardware and difficulties using module software. | In StudentHome click on the 'Help' tab and 'Computing help'<br>Telephone: +44 (0)1908 653972 |
| Obtaining copies of published articles, literature searches, searching the internet and using other Library resources | In StudentHome go to the 'Services' section and click on 'Library services'<br>Telephone: +44 (0)1908 659001<br>Email: library-help@open.ac.uk<br>Website: www.open.ac.uk/library<br>Write to:<br>Library Services<br>The Open University<br>Walton Hall<br>Milton Keynes MK7 6AA |

| If you have queries or problems relating to: | Whom to contact: |
|---|---|
| Advice for students with disabilities. | In StudentHome go to the 'Services' section and click on 'Services for disabled students'<br>Telephone: +44 (0)1908 653745<br>Textphone: +44 (0)1908 655978<br>Email: Disabled-student-resources@open.ac.uk<br>Website: www.open.ac.uk/disability<br>Write to:<br>The Learner Support Team at your Regional Centre<br>or<br>Disabled Students Resource Team<br>The Open University<br>Hammerwood Gate<br>Kents Hill<br>Milton Keynes MK7 6BY |
| Module registration. | In StudentHome click on the 'Help' tab<br>Telephone: +44 (0)845 300 6090<br>Email: general-enquiries@open.ac.uk<br>Write to:<br>The Learner Support Team at your Regional Centre<br>or<br>Student Registration and Enquiry Service<br>The Open University<br>PO Box 197<br>Milton Keynes MK7 6BJ |
| Study choice and degree pathway planning. | The Physical Science Student Support Team<br>Telephone: +44 (0)845 366 0474<br>Email: physical-science-support@open.ac.uk |
| All other queries including: study issues, withdrawal from the module, change of name or address. | The Physical Science Student Support Team<br>Telephone: +44 (0)845 366 0474<br>Email: physical-science-support@open.ac.uk |
| Comments on the module itself or on the assignments (e.g. suspected errors, suggestions for improvements). | The SM358 Curriculum Manager<br>Department of Physics and Astronomy<br>The Open University<br>Milton Keynes MK7 6AA<br>E-mail: OU-Science@open.ac.uk<br>(Please quote the module code, SM358, in the subject field.) |

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